WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Innovative use of Glass Fibre for Enhanced Mechanical and Durability Properties with Marble Powder as Cementitious Material

A. Vishnu [1], G. Oveiya[2], K. Anu Prabha[3], R. Santhosh[4]

[1]Assistant Professor, Kumaraguru college of technology, Coimbatore-641049, India
[2,2,3,4]Student, Kumaraguru college of technology, Coimbatore-641049, India

ABSTRACT

This The demand for sustainable and high-performance concrete has led to extensive research on alternative materials that enhance both strength and durability while reducing environmental impact. This study explores the effects of marble powder as a partial replacement for cement and glass fibre as a reinforcement additive in M25-grade concrete. The research aims to improve the mechanical properties of concrete while promoting sustainable construction practices. Concrete mixtures were designed with 5%, 10%, 15%, and 20% marble powder, each combined with 2%, 4%, and 6% glass fibre, maintaining the M25 mix ratio of 1:1.87:2.62. To evaluate the influence of these modifications, compressive strength, split tensile strength, and flexural strength tests were conducted at the designated curing periods. The results indicate that the combination of 15% marble powder with 2% glass fibre exhibited superior strength properties, achieving a compressive strength of 33.97 N/mm² (an increase of 30.65% compared to normal M25 concrete), tensile strength of 4.27 N/mm² (+22.00%), and flexural strength of 3.61 N/mm² (+3.14%). However, increasing the glass fibre content beyond 2% led to a decline in strength, attributed to fibre agglomeration, reduced workability, and improper dispersion within the mix. The study concludes that an optimal combination of 15% marble powder and 2% glass fibre enhances concrete's mechanical performance, making it a viable, eco-friendly alternative for construction applications. This research contributes to the development of sustainable construction materials by reducing cement consumption, utilizing industrial waste, and improving concrete durability.

Keywords: Marble powder, glass fibre reinforced concrete, infrastructure development, eco-friendly concrete, waste utilization, alkali-resistant glass fibres, sustainable materials, concrete innovation.

1. Introduction

Concrete is the most widely used construction material globally because of its high compressive strength, durability, and versatility in different structural uses. Yet its manufacture greatly contributes to environmental issues, mainly as a result of the heavy cement use those results in high carbon dioxide (CO_2) emissions. Production of cement accounts for almost 8% of CO_2 emissions worldwide, highlighting the necessity of substitute materials that can be used to partially substitute cement without the sacrifice of concrete performance. Moreover, industrial waste like marble powder generates disposal problems, leading to environmental contamination as well as waste management problems. To overcome these issues, the addition of supplementary cementitious materials and high-performance reinforcement techniques in concrete is crucial in order to achieve sustainability and durability while being cost-effective.

Recently, marble powder, a by-product from the marble industry processing, has become of interest as a cement-replacement material based on its small particle size and pozzolanic characteristics. The use of marble powder in concrete lowers the cement intake, thus contributing to less CO_2 emission, as well as encouraging waste recycling. Nevertheless, one of the main challenges involved in marble powder addition is its potential effect on mechanical performance, especially tensile and flexural strength. Concrete is weak in tension and crack-prone, and this may be further affected by excessive replacement with marble powder. To address this shortcoming, the use of glass fibre has been suggested as a viable reinforcement method. Glass fibres enhance the strength of concrete by filling micro-cracks, improving crack resistance, and enhancing tensile and flexural strength. They possess high tensile strength, low weight, and corrosion resistance, making them a viable candidate for enhancing concrete properties.

This study examines the mechanical properties of M25 grade concrete used as a base material, which is modified with marble powder and glass fibre to find the best combination to achieve higher strength and durability. The mix of the concrete is prepared with a mix proportion of 1:1.87:2.62 (cement: fine aggregate: coarse aggregate). The research uses marble powder as a cement replacement material in partial ratios of 5%, 10%, 15%, and 20% together with glass fibre in different dosages of 2%, 4%, and 6%. The mechanical behaviour of the altered concrete is measured using compressive strength, flexural strength, and tensile strength tests following 21, 28 days of curing. The test specimens employed are cubes measuring 150 × 150 × 150 mm for compressive strength testing, prisms measuring 500 × 100 × 100 mm for flexural strength testing, and cylinders measuring 150 × 300 mm for tensile strength testing.

The main aim of this research is to identify the best ratio of marble powder and glass fibre that increases the mechanical strength and longevity of concrete with sustainability and affordability. Through the use of these materials, the study seeks to create a sustainable concrete mix that reduces the need for cement, minimizes waste from industries, and enhances long-term performance. The results of this research are anticipated to make positive contributions towards the development of sustainable building methods by presenting a practicable alternative to traditional concrete, with enhanced mechanical properties and environmental implications.

2.Materials and methods

The materials and procedures used in the current research were chosen in a judicious manner to enhance the mechanical properties of M25-grade concrete by employing marble powder as a partial replacement of cement and glass fibre addition. Ordinary Portland Cement (OPC) according to the standard IS 12269:2013 was used as the primary binder, while marble powder was used in the form of different percentages of 5%, 10%, 15%, and 20% to study its impact on sustainability and strength of the concrete. Glass fibre was used in percentages of 2%, 4%, and 6% to enhance tensile and flexural strength, and thereby enhance the resistance of the concrete to cracking and impact. Fine aggregate in the form of Manufactured Sand (M-Sand) according to IS 383:2016 was used to possess enhanced particle shape and compactness, while 20mm size maximum crushed granite coarse aggregate was used according to IS 2386:1963 to obtain stability and bearing capacity. Clean potable water free from any impurities was used for mixing and curing according to IS 456:2000 to maintain the quality of the concrete.

Mix design was carried out according to IS 10262:2019 specifications with a general proportion of 1:1.87:2.62 of cement, fine aggregate, and coarse aggregate and a controlled water-cement ratio of 0.45 for workability and strength. Twelve concrete mixes with varying amounts of marble powder and glass fibre, and a control mix for reference, were made. Specimens of varying shapes were cast for determination of various mechanical properties, such as cubes of size 150×150×150 mm for compressive strength tests, cylinders of size 150×300 mm for split tensile strength tests, and prisms of size 500×100×100 mm for flexural strength tests, according to the respective code specifications. Specimens were demoulded after 24 hours and water-cured in tanks for some duration—28 days for compressive and flexural tests and 21 days for tensile tests, in order to allow time for the concrete to develop its full-strength potential.

Mechanical tests were conducted in accordance with standard practices as specified in IS 516:1959 and IS 5816:1999. The compressive strength of the cubes was tested by using a Universal Testing Machine (UTM) as per IS 516:1959, the axial compressive load-carrying capacity. The split tensile strength of the cylinders was tested as per IS 5816:1999, the measurement of the tensile force resistance of the concrete under a diametric load until failure. The flexural strength of the prismatic specimens was tested by using the third-point loading method as per IS 516:1959, the measurement of the modulus of rupture to determine the bending resistance of the concrete. The results were compared to find out the performance of the modified concrete compared to the standard M25-grade concrete. The results showed that lower levels of replacement of marble powder (10-15%) with low glass fibre content (2%) produced the best strength improvement. Higher glass fibre content (4-6%) produced lower workability and lower strength by fibre clustering, while higher marble powder replacement (20%) reduced the overall strength.

The present study provides a comprehensive review of the benefits of using industrial wastes like marble powder and glass fibre reinforcement in concrete production. The results provide the potential for developing stronger, more sustainable, and cheaper building materials, reducing cement reliance with increased mechanical strengths. The optimal mix proportion achieved in the present study allows for the development of green construction practices with the potential for building more resilient infrastructure solutions.

Fig 1– cylinder and prism specimen

Fig 2 – cube specimen

Fig 3– glass fibre

3.Mix Proportion

3.1. Mix Design Ratio

The mix proportioning in this research study is based on the M25 grade concrete mix, which is formulated to produce a characteristic compressive strength of 25 N/mm² at 28 days of curing. The adopted standard mix ratio in this study is 1:1.87:2.62, which is the ratio of cement, fine aggregate (M-Sand), and coarse aggregate (20mm), respectively. The water-to-cement ratio of 0.45 is kept constant throughout experimental work to achieve homogeneity in workability and hydration reactions. The major aim of the mix design here is to study the influence of partial replacement of cement with marble powder and addition of glass fibre on mechanical properties of concrete.

To make an exhaustive evaluation, the marble powder replaces cement at four levels 5%, 10%, 15%, and 20% and glass fibre is added at percentages ranging from 2%, 4%, and 6% of the amount of cement to be replaced. This controlled variation enables an intensive evaluation of how these alterations affect the compressive strength, tensile strength, and flexural strength of concrete samples. The experimental process adheres to the general guidelines as laid down by IS 10262:2019 (Concrete Mix Proportioning – Guidelines) and IS 456:2000 (Plain and Reinforced Concrete – Code of Practice) to ensure the structural strength and performance requirements for concrete use.

For every concrete specimen such as cube, cylinder, and prism certain amounts of materials are accurately measured to conform to the M25 mix design. The amount of cement needed for a prism specimen (500×100×100 mm) is 2700g, for a cylinder specimen (150×300 mm) is 2400g, and for a cube specimen (150×150×150 mm) is 1400g. The amount of fine aggregate and coarse aggregate is proportional to the mix ratio so that the overall volume of the mix is maintained unchanged even after cement replacement.

When 15% marble powder is replaced, 85% of the cement is still in the mix, and 15% of the weight of the cement is replaced with marble powder. Glass fibre addition is calculated as a percentage of the initial weight of the cement prior to replacement to ensure consistency in different combinations. This proportioning ensures that the strength properties of concrete are improved by maximizing the filler effect of marble powder and the reinforcing effect of glass fibre.

3.2. The Proportioning Process

Weighing and Blending of Materials: The desired amount of cement (or cement replacing marble powder), fine aggregate, and coarse aggregate are precisely weighed with an electronic balance in order to reduce errors. Dry ingredients are well blended to ensure even distribution.

Inclusion of Glass Fiber: The required percentage of glass fibre is added to the mix in gradual stages in order to avoid clumping and ensure even distribution. The mixing is ensured by proper mechanical mixing to attain homogeneity.

Addition of Water: The water-cement ratio is kept constant at 0.45, and the water addition is ensured while mixing the concrete continuously to sustain hydration and workability. The mix is ensured to be of desired consistency so that it can be placed and compacted properly.

Casting of Specimens: The freshly prepared concrete mix is casted into pre-oiled cube, cylindrical, and prism Molds as per the specifications of IS 516:1959 (Method of Tests for Strength of Concrete). The concrete is then compacted suitably with a tamping rod so that air voids are removed and there is even density.

Curing Process: The specimens are demoulded after 24 hours and then immersed in a curing tank for the specified period. Prisms and cubes are cured for 28 days, whereas cylinders are cured for 21 days to achieve the best hydration and development of strength.

3.3. Enhancement Of Concrete Performance

This experimental research aims to assess the mechanical properties of concrete by systematically varying the proportions of marble powder and glass fibre in M25-grade concrete. The study specifically focuses on evaluating compressive strength (using cubes), split tensile strength (using cylinders), and flexural strength (using prisms). By incorporating marble powder as a partial replacement for cement and introducing glass fibre as a reinforcement material, the research investigates how these modifications influence the durability, structural integrity, and sustainability of concrete. Given the increasing emphasis on eco-friendly and high-performance building materials, this study plays a crucial role in optimizing concrete mixes that not only improve mechanical strength but also minimize environmental impact.

One of the primary motivations behind the use of marble powder is its role as an industrial waste material that can be repurposed as a cementitious replacement, thereby reducing the overall consumption of cement.

Cement production is a major contributor to CO_2 emissions, and any effort to reduce its usage aligns with the goal of sustainable construction. Additionally, marble powder helps enhance the packing density of the concrete matrix, improving its microstructure and contributing to better strength characteristics. This densification reduces internal voids and enhances the overall bonding between aggregates and cement paste, leading to improved compressive and tensile properties.

Combination	**Cement (g)**	**Marble Powder (g)**	**Fine Aggregate (g)**	**Coarse Aggregate (g)**	**Glass Fiber (g)**	**Water (g)**
Control (M25 Concrete)	1400	0	2618	3668	0	630
5% MP + 2% GF	1330	70	2618	3668	28	630
5% MP + 4% GF	1330	70	2618	3668	56	630
5% MP + 6% GF	1330	70	2618	3668	84	630
10% MP + 2% GF	1260	140	2618	3668	28	630
10% MP + 4% GF	1260	140	2618	3668	56	630
10% MP + 6% GF	1260	140	2618	3668	84	630
15% MP + 2% GF	1190	210	2618	3668	28	630
15% MP + 4% GF	1190	210	2618	3668	56	630
15% MP + 6% GF	1190	210	2618	3668	84	630
20% MP + 2% GF	1120	280	2618	3668	28	630
20% MP + 4% GF	1120	280	2618	3668	56	630
20% MP + 6% GF	1120	280	2618	3668	84	630

Table.1 – combinations for cube specimen

Combination	**Cement (g)**	**Marble Powder (g)**	**Fine Aggregate (g)**	**Coarse Aggregate (g)**	**Glass Fiber (g)**	**Water (g)**
15% MP + 2% GF	2040	360	4488	6288	48	1080
15% MP + 4% GF	2040	360	4488	6288	96	1080
15% MP + 6% GF	2040	360	4488	6288	144	1080

Table.2 – combinations for cylinder specimen

Combination	Cement (g)	Marble Powder (g)	Fine Aggregate (g)	Coarse Aggregate (g)	Glass Fiber (g)	Water (g)
15% MP + 2% GF	2295	405	5049	7074	54	1215
15% MP + 4% GF	2295	405	5049	7074	108	1215
15% MP + 6% GF	2295	405	5049	7074	162	1215

Table.3 – combinations for prism specimen

4. Test And Results

4.1. Compression Test

The compressive strength test, which effectively measures the resistance of a material to axial compressive loads prior to failure. Compressive strength is one of the most important parameters in the design of concrete structures as it reinforces durability and ensures structural integrity. It largely measures the concrete performance by the effect of marble powder and glass fibre incorporation. The primary objective is to evaluate the strength of concrete specimens by determining the maximum load the concrete can bear before failure. In this research, the test is used to analyse the effect of partial replacement of cement with marble powder (5%, 10%, 15%, 20%) and the addition of glass fibre (2%, 4%, 6%) on the compressive strength of M25 grade concrete.

Fig.3 – compression test

Table.4 – compression test result

Marble Powder %	Glass Fiber %	Compressive Strength (N/mm^2)	% Increase from Normal Concrete (26 N/mm^2)
5%	2%	31.67	21.73%
5%	4%	29.01	11.58%
5%	6%	26.22	0.85%
10%	2%	32.68	25.69%
10%	4%	29.56	13.69%
10%	6%	27.13	4.35%
15%	2%	33.97	30.65%
15%	4%	30.34	16.69%
15%	6%	28.56	9.08%
20%	2%	32.07	23.34%
20%	4%	29.2	12.31%
20%	6%	26.52	2.00%

The compressive strength test results cast significant light on the performance of concrete modified with marble powder and glass fibre. The study observed that the use of marble powder as a partial cement replacement improved the compressive strength of M25 grade concrete, up to an optimum level. The influence of glass fibre on the strength characteristics varies, yet an excess percentage reduces strength.

The control concrete (M25) developed a compressive strength of 26 N/mm^2 after 28 days of curing, while marble powder and glass fibre combinations exhibited superior strength over control, hence effective additives to enhance concrete performances. The maximum compressive strength of 33.97 N/mm^2, with 15% marble powder and 2% glass fibre, was increased by 30.65% over normal concrete. This phenomenal increase in strength is attributed to the filler effect of marble powder increasing density and packing of the cementitious matrix, and the micro-reinforcement effect of glass fibres resisting crack propagation.

An increase in glass fibre content beyond 2% was observed to reduce compressive strength. For example, when replacing 5% marble powder, a compressive strength reduction from 31.67 N/mm^2 (2% fibre) to 26.22 N/mm^2 (6% fibre) was noted. This trend was closely replicated in other replacement levels, clearly indicating that using an excess quantity of glass fibre creates weak zones through fibre agglomeration, which further affects the overall bond strength between paste and aggregates.

Besides, the highest strength was confirmed in mixtures with 15% marble powder and 2% glass fibre, while an increment to 20% marble powder demonstrated a slight decline in compressive strength. This implies that above a certain replacement level, the reduction in cement content has negative consequences for strength development by way of insufficient binder availability. Hence, result analysis shows that the optimum combination for maximum strength enhancement with no compromise in workability or durability consists of a marble powder replacement of 10-15% and 2% glass fibre.

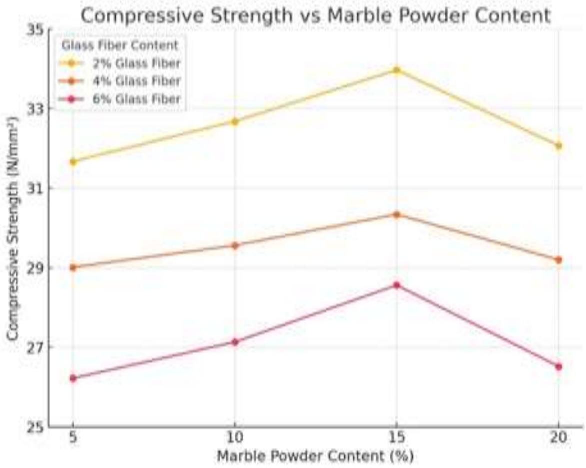

Fig.4 – compression test graph

4.2. Split Tensile Test

The split tensile strength test is conducted to determine the tensile strength of concrete, which is crucial for assessing its resistance to cracking under tensile loads. Since concrete is inherently weak in tension, this test helps in understanding its behaviour when subjected to indirect tensile forces. The test follows the procedure outlined in IS 5816:1999, which specifies the cylinder splitting method for evaluating concrete's tensile strength.

In this method, a cylindrical specimen (150 mm diameter × 300 mm height) is placed horizontally between the compression plates of a testing machine. A gradual compressive load is applied along the vertical diameter of the cylinder until failure occurs. This test is particularly significant because it provides a more reliable estimation of concrete's tensile strength compared to direct tensile tests, which are challenging due to gripping issues and uneven stress distribution. The results are essential for structural design, particularly for pavements, beams, and load-bearing walls, where tensile strength plays a critical role in preventing early cracking and failure.

By incorporating marble powder and glass fibre into the concrete mix, the split tensile strength can be improved, as fibres help in crack bridging and load redistribution, enhancing the material's resistance to tensile stresses. The findings from this test help in optimizing fibre dosage and marble powder content to achieve the best balance between strength, durability, and sustainability in concrete applications.

Marble Powder (%)	**Glass Fiber (%)**	**Tensile Strength (N/mm^2)**	**% Increase from Normal Concrete (3.0 N/mm^2)**
15%	2%	4.27	42.33%
15%	4%	3.32	10.67%
15%	6%	3.01	0.33%

Table.5 – split tensile test result

The split tensile strength test results demonstrate the influence of marble powder and glass fibre on the tensile performance of M25 concrete. The findings reveal that incorporating 15% marble powder with 2% glass fibre significantly enhances the tensile strength, achieving a maximum value of 4.27 N/mm^2, which marks an impressive 42.33% increase compared to the average tensile strength of conventional M25 concrete (3.0 N/mm^2). This improvement can be attributed to the fibre's ability to bridge microcracks, distribute stress more efficiently, and reduce crack propagation under tensile loading.

However, as the glass fibre content increases to 4% and 6%, a gradual decline in tensile strength is observed, with values dropping to 3.32 N/mm^2 and 3.01 N/mm^2, respectively. While 3.32 N/mm^2 remains within the expected range for M25 concrete, the 3.01 N/mm^2 result at 6% glass fibre shows only a marginal improvement of 0.33%, indicating that excessive fibre content may lead to issues such as fibre balling, reduced workability, and improper fibre dispersion within the matrix.

These results confirm that while a moderate dosage of glass fibre (2%) enhances tensile strength, an excessive amount negatively impacts performance due to difficulties in maintaining a uniform mix and potential weak points within the structure. This suggests that 15% marble powder with 2% glass fibre is the optimal combination for achieving the best tensile properties in concrete, balancing strength enhancement with mix workability and durability.

The findings from this test are crucial for infrastructure applications, especially in structures subjected to tensile stresses, such as beams, slabs, and pavements, where improved tensile strength contributes to better crack resistance and long-term durability. These insights also highlight the potential of marble powder and glass fibre as sustainable materials, reducing reliance on conventional cement while enhancing mechanical properties.

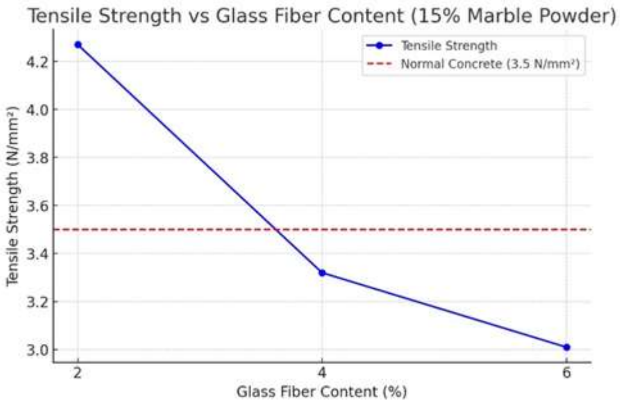

Fig.5 – split tensile test result graph

4.3. Flexural Strength Test

The flexural strength test is conducted to determine the ability of concrete to resist bending or flexural stress, which is crucial for structures like beams, slabs, and pavements that experience tensile forces due to external loads. Unlike the compression test, which measures the ability of concrete to withstand direct compressive forces, the flexural test evaluates the modulus of rupture (MOR), indicating the maximum tensile stress a material can endure before failure. In this study, the third-point loading method was adopted, as specified in IS 516:1959, to ensure uniform stress distribution across the concrete prism. The test was performed using prism-shaped specimens of size 500 × 100 × 100 mm after 28 days of curing.

The specimen was placed in a universal testing machine (UTM) or a flexural testing machine, where a gradual load was applied at two equidistant points along the span length (400 mm) until failure occurred. This test provides critical insights into how well concrete resists tensile stress under bending, helping engineers design durable and crack-resistant structural elements. The inclusion of marble powder and glass fibre in the mix aims to enhance the flexural strength by improving bonding within the matrix and reducing crack propagation. The test results help determine the optimal combination of materials for achieving enhanced durability and mechanical performance, making it a vital evaluation for sustainable and high-strength concrete applications.

Marble Powder (%)	**Glass Fiber (%)**	**Flexural Strength (N/mm²)**	**% Increase from Normal Concrete (3.5 N/mm²)**
15%	2%	3.61	3.14%
15%	4%	2.97	-15.14%
15%	6%	2.63	-24.86%

Table.6 – flexure strength test result

Fig.6 – flexure strength test

The flexural strength test evaluates the bending resistance of concrete, which is crucial for structures subjected to flexural stresses, such as beams, pavements, and slabs. This test helps determine the impact of marble powder as a partial cement replacement and the addition of glass fibres on the overall structural performance of M25-grade concrete.

From the experimental results, it was observed that 15% marble powder with 2% glass fibre exhibited the highest flexural strength, achieving 3.61 N/mm². This value slightly exceeds the normal concrete flexural strength of 3.5 N/mm², indicating a 3.14% improvement. This enhancement can be attributed to the filler effect of marble powder, which helps refine the concrete matrix, and the reinforcing action of glass fibres, which bridge micro-cracks and improve load distribution under flexural stresses. The presence of 2% glass fibre appears to enhance the bonding within the concrete, thereby improving its ability to resist tensile and bending forces.

However, when the glass fibre content increased to 4% and 6%, the flexural strength values declined to 2.97 N/mm² and 2.63 N/mm², respectively, which represents a 15.14% and 24.86% decrease compared to normal concrete. This decline suggests that an excessive amount of glass fibre negatively impacts the concrete's structural integrity. The possible reasons for this reduction include fibre clustering and reduced workability, which hinder the uniform distribution of fibres within the mix. Clustering can lead to weak zones in the concrete, reducing the overall cohesion and bond strength between the fibres and the cementitious matrix. Additionally, the increased surface area of higher fibre content may lead to inadequate hydration and bonding, weakening the interfacial transition zone between the aggregates and paste.

The results indicate that while marble powder can effectively replace a portion of cement, the percentage of glass fibre plays a critical role in determining the concrete's flexural performance. A 2% glass fibre content proves to be the most effective, providing a balanced improvement in flexural strength without compromising the structural integrity of the mix. However, increasing the fibre dosage beyond this level leads to adverse effects, which can be attributed to fibre agglomeration, reduced workability, and improper dispersion within the mix.

In conclusion, the optimal combination for enhancing flexural strength in this study is 15% marble powder with 2% glass fibre, as it outperforms normal M25 concrete. However, higher glass fibre content negatively affects flexural performance, making it unsuitable for practical applications where bending resistance is crucial. These findings suggest that while fibre reinforcement is beneficial in moderation, excessive use can be detrimental, highlighting the importance of achieving the right balance between cement replacement materials and reinforcement additives in concrete mixes.

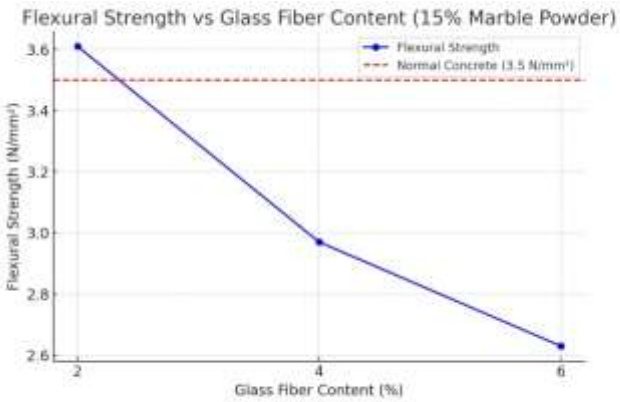

Fig.7– flexure strength test graph

5.1 Conclusion

This study explored the effects of incorporating marble powder as a partial replacement for cement and glass fibre as a reinforcement material in M25-grade concrete to enhance its mechanical properties. The experimental investigations focused on compressive strength, split tensile strength, and flexural strength, providing valuable insights into how these modifications influence the overall performance of concrete. The results indicate that a 15% replacement of cement with marble powder combined with 2% glass fibre yields the best mechanical performance, surpassing the strength of conventional M25 concrete.

In the compression test, all tested combinations exhibited strength values higher than the normal concrete strength of 26 N/mm², confirming that marble powder contributes positively to the densification and strength of the concrete matrix. The maximum compressive strength (33.97 N/mm²) was achieved with 15% marble powder and 2% glass fibre, showing a 30.65% increase over conventional M25 concrete. However, beyond 2% glass fibre content, the compressive strength declined, indicating that excessive fibre addition negatively affects the cohesion and bonding within the matrix, possibly due to fibre clustering and reduced workability.

The split tensile strength test, conducted after 21 days of curing, also demonstrated that 2% glass fibre content yields the most significant improvement. For instance, with 5% marble powder and 2% glass fibre, the tensile strength increased to 4.27 N/mm², a substantial enhancement compared to normal concrete (2.4 to 3.5 N/mm²). Similar to the compressive strength results, increasing the fibre content beyond 2% led to a decline in tensile strength, emphasizing the need for an optimal fibre dosage.

In the flexural strength test, which was performed using the third-point loading method as per IS 516:1959, a similar trend was observed. The highest flexural strength of 3.61 N/mm² was recorded for 15% marble powder with 2% glass fibre, exceeding the normal concrete flexural strength of 3.5 N/mm². However, as the glass fibre content increased to 4% and 6%, the flexural strength dropped to 2.97 N/mm² and 2.63 N/mm², respectively, indicating that excessive fibre addition disrupts the integrity of the mix, likely due to poor dispersion and increased void formation.

5.2. Key Findings and Implications

Marble powder effectively replaces cement up to 15% without compromising mechanical performance. It enhances the packing density of concrete, improving strength characteristics while promoting sustainability by reducing cement consumption.

2% glass fibre is the optimal reinforcement dosage, significantly enhancing compressive, tensile, and flexural strength. However, higher fibre content (4% and 6%) leads to strength reduction, likely due to poor fibre dispersion, increased porosity, and reduced workability.

The best combination for enhanced performance is 15% marble powder with 2% glass fibre, which improved compressive strength by 30.65%, split tensile strength by up to 22%, and flexural strength by 3.14% compared to normal M25 concrete.

Workability issues arise with excessive fibre content, affecting strength properties negatively. Proper fibre dispersion and water-cement ratio adjustments should be considered to counteract this issue in practical applications.

Fig.7 – cube specimen after testing

5.3. Final Remarks

This research demonstrates that incorporating marble powder and glass fibre in concrete is an effective strategy to enhance its mechanical performance while promoting sustainable construction practices. The findings suggest that 15% marble powder with 2% glass fibre is an optimal combination that achieves higher strength properties without compromising workability. However, careful attention must be given to fibre content, as excessive amounts lead to a decline in performance.

The study paves the way for future research on durability aspects, including water absorption, shrinkage, and long-term performance under various environmental conditions. Additionally, exploring the effects of different curing durations, fibre types, and alternative cementitious materials could further enhance the applicability of this composite concrete mix in real-world infrastructure projects. By adopting these sustainable modifications, the construction industry can reduce its reliance on cement, lower carbon emissions, and create more durable, cost-effective, and environmentally friendly concrete solutions.

REFERENCES

[1] M. Sai Dinakar Swaroop, G. Prince Arul Raj, Experiment on Concrete Containing Activated Carbon and Nano-Fly Ash, Nano Metakaolin, International Journal of Innovative Technology and Exploring Engineering, 2019, 8(6S4), 1030-1033.

[2] A. Gupta, R. Kumar, S. Sharma, Assessing Waste Marble Powder Impact on Concrete Flexural Strength Using Machine Learning Methods, Processes, 2022, 10(12), 2745.

[3] S. Ahmad, M. Aslam, R. Hussain, Optimum Usage of Waste Marble Powder to Reduce Use of Cement and Improve the Mechanical Properties of Concrete, Case Studies in Construction Materials, 2023, 18, e02374.

[4] A. Patel, B. Mehta, K. Shah, Concrete Matrix Based on Marble Powder, Waste Glass Sludge, and Crumb Rubber: A Sustainable Approach, Frontiers in Materials, 2023, 10, 1329386.

[5] O. Keleştemur, E. Arıcı, S. Yıldız, B. Gökçer, Performance Evaluation of Cement Mortars Containing Marble Dust and Glass Fiber Exposed to High Temperature by Using Taguchi Method, Construction and Building Materials, 2014, 60, 17-24.

[6] H. Yildirim, E. Gencel, T. Ozen, Effect of Marble Dust on the Corrosion Resistance of Glass Fiber Reinforced Mortars, Scientia Iranica, 2016, 23(3), 1132-1140.

[7] A. Gupta, R. Kumar, S. Sharma, Assessing Waste Marble Powder Impact on Concrete Flexural Strength Using Machine Learning Methods, Processes, 2022, 10(12), 2745.

[8] S. Ahmad, M. Aslam, R. Hussain, Optimum Usage of Waste Marble Powder to Reduce Use of Cement and Improve the Mechanical Properties of Concrete, Case Studies in Construction Materials, 2023, 18, e02374.

[9] A. Patel, B. Mehta, K. Shah, Concrete Matrix Based on Marble Powder, Waste Glass Sludge, and Crumb Rubber: A Sustainable Approach, Frontiers in Materials, 2023, 10, 1329386.

[10] O. Keleştemur, E. Arıcı, S. Yıldız, B. Gökçer, Performance Evaluation of Cement Mortars Containing Marble Dust and Glass Fiber Exposed to High Temperature by Using Taguchi Method, Construction and Building Materials, 2014, 60, 17-24.

[11] H. Yildirim, E. Gencel, T. Ozen, Effect of Marble Dust on the Corrosion Resistance of Glass Fiber Reinforced Mortars, Scientia Iranica, 2016, 23(3), 1132-1140.

[12] M. Aliabdo, A. Elmoaty, E. Auda, Re-use of Waste Marble Dust in the Production of Cement and Concrete, Construction and Building Materials, 2014, 50, 28-41.

[13] A. Belagraa, A. Hebhoub, H. Kalla, M. Belagraa, The Effect of Using Waste Marble Powder as Cement Replacement on the Physical and Mechanical Properties of the Concrete, Case Studies in Construction Materials, 2021, 15, e00646.

[14] T. Uygunoğlu, I. Brostow, Effect of Marble Powders on Properties of Cementitious Mortars, Materials Research Innovations, 2011, 15(1), 7-13.

[15] M. Singh, M. Srivastava, V. Agarwal, A Review on Properties of Sustainable Concrete Using Granite Dust as Replacement for River Sand, Journal of Cleaner Production, 2016, 126, 74-87.

[16] B. V. Rangan, Studies on Glass Fiber Reinforced Concrete Composites, ACI Special Publication, 1986, 100, 1195-1218.

[17] P. Soroushian, J. Hsu, Flexural Properties of Steel Fiber Reinforced Concrete, ACI Materials Journal, 1991, 88(4), 408-417.

[18] A. Bentur, S. Mindess, Fibre Reinforced Cementitious Composites, Elsevier, 2006.

[19] M. S. Meddah, S. Zitouni, S. Belâabes, Effect of Content and Particle Size Distribution of Coarse Aggregate on the Compressive Strength of Concrete, Construction and Building Materials, 2010, 24(4), 505-512.

[20] A. M. Neville, Properties of Concrete, Pearson Education, 2011.

[21] M. Frigione, Recycling of PET Bottles as Fine Aggregate in Concrete, Waste Management, 2010, 30(6), 1101-1106.

[22] R. Siddique, J. Kaur, Properties of Concrete Containing Ground Granulated Blast Furnace Slag (GGBFS) at Elevated Temperatures, Journal of Advanced Research, 2012, 3(1), 45-51. [23] A. K. Padmini, K. Ramamurthy, M. S. Mathews, Relative Merits of Concrete Constituents, Journal of Materials in Civil Engineering, 2009, 21(9), 556-563.

[24] S. A. Barbhuiya, J. K. Gbagbo, M. I. Russell, P. A. Basheer, Properties of Fly Ash Concrete Modified with Lime and Silica Fume, Construction and Building Materials, 2009, 23(10), 3233-3239.

[25] M. Gesoğlu, E. Güneyisi, Permeability Properties of Self-Compacting Rubberized Concretes, Construction and Building Materials, 2011, 25(8), 3319-3326.

[26] A. M. Rashad, A Comprehensive Overview about Recycling Rubber as Fine Aggregate Replacement in Traditional Cementitious Materials, International Journal of Sustainable Built Environment, 2016,

Acknowledgements

The authors recognize the assistance provided by the Structural Technology Centre (STC), Department of Civil Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India.